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BIRCH TS TO MOOSE LAKE TS REPLACEMENT OF DETERIORATED CONCRETE FOOTINGS UNDER TOWER 266 USING VLT POLYMER CONCRETE

Report No. 91-216-K

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ABSTRACT

Deteriorated footings for the Birch TS to Moose Lake TS line north of Thunder Bay were recently replaced using a polymer concrete. The process involved jacking up the tower legs, removing the deteriorated concrete, and placing the new footings. The use of a polymer concrete made it possible to complete the process in less than three hours. Details of the field procedures are outlined in this report.

job	file	date	report no.
42-001-134	842.44	December 19, 1991	91-216-K

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To Mr. Rob Macey
Transmission Lines Supervisor
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Attn: Mr. Art Miron

BIRCH TS TO MOOSE LAKE TS REPLACEMENT OF DETERIORATED CONCRETE FOOTINGS UNDER TOWER 266 USING VLT POLYMER CONCRETE

1.0 INTRODUCTION

At the request of Mr. A. Miron, a field demonstration was carried out on July 8 and 9, 1991, to replace deteriorated concrete footings with new footings made with VLT polymer concrete. The purpose of the demonstration was to instruct field personnel in the safety, handling, mixing and placing procedures. VLT is a two component polymer (resin and catalyst). Polymer concrete can be produced by mixing it with an appropriate amount of graded aggregate. The VLT polymer concrete was used to replace the deteriorated footings under Legs 2 and 3 of Tower 266 on the Birch TS to Moose Lake TS line (Fig. 1). The tower line was constructed around 1946 using High Aluminous cement concrete footings. The major damage to the existing concrete footings appears to be due to freeze/thaw action (Fig. 2)

2.0 REPAIR PROCEDURES

2.1 Raising The Tower

Wooden planks (≈ 8" x 8" to 10" x 10") were laid on the rock surface on both sides of a tower leg and levelled to provide support for the mechanical jacks during lifting of the

tower leg. An I-beam was located along the outside of the tower leg as shown in Figure 3. Chains were then wrapped around the I-beam and tower leg, and a pulley was connected to the opposite tower leg and tensioned to hold the I-beam in position. The tower leg was then raised using two mechanical jacks just enough to take the load off the footing.

2.2 Removal Of Deteriorated Concrete Footing

The condition of the existing concrete footings prior to and during removal is summarized in Table 1, and shown in Figures 2 and 4.

Once the tower was raised, an air driven jackhammer was used to remove the existing footing. A sledge and mason's hammer as well as shovels were used to remove the debris during jackhammering. The concrete under both tower legs 2 and 3 disintegrated into rubble, with very few chunks of concrete being removed intact. This is indicative of a deteriorated concrete with low compressive strength. A sample of the concrete, removed intact from one of the better footings, was forwarded to the Civil Research laboratory for testing. The compressive strength of the concrete varied between 13 and 16 MPa and was significantly lower than that would be expected for a tower footing concrete. The typical compressive strength of the VLT polymer concrete is 100 MPa.

2.3 Preparation Of Rock Surface and Construction Of Formwork

Details of rock surface preparation and construction and sealing of the formwork are outlined in Table 2.

After removing the existing concrete, compressed air was used to remove loose debris along the sides and underneath the baseplate (Figure 5). No further surface preparation was required because the rock surface was relatively clean.

For tower leg 2, 42" diameter Sonotube was cut to fit the contour of the rock and installed around the periphery of the baseplate. The Sonotube was held in position and sealed along the bottom using the loose concrete debris that had been removed earlier. The neat VLT resin and catalyst that had been previously mixed was used to prime the rock surface (Figure 6A). This material was brushed onto the rock surface to ensure adequate adhesion of the polymer concrete to rock because of the high aggregate/resin ratio used (ie. A/R-13.0/1.0).

Based on the observations made on tower leg 2 repair, the procedures were modified for tower leg 3 as follows:

a) Wooden formwork was installed around the tower baseplate instead of Sonotube to reduce the volume of polymer concrete (Figure 6B). This also led to a reduction in installation time of the formwork.

b) The wooden formwork was lined with plastic for ease in stripping after hardening of the polymer concrete. Also, the wooden formwork could be reused, if necessary, reducing material costs.

c) Instead of priming the surface with neat resin, the first batch of polymer concrete was mixed at a lower aggregate/resin ratio of 8.5/1.0 to ensure that sufficient resin was available to wet the rock surface and provide adequate adhesion.

3.0 MIXING OF POLYMER CONCRETE

The type of mixing equipment and mixing time for the polymer concrete prior to placing are summarized in Table 2. Also, included are observations made during mixing and placing of polymer concrete into the formwork. For all the batches of polymer concrete, the neat resin and catalyst were initially mixed for a minimum of two minutes using a gas powered drill and jiffler mixer, prior to adding the aggregate (Figure 7). The polymer concrete was mixed at aggregate/resin ratios varying between 8.5/1.0 and 13.0/1.0.

The new footing for tower leg 2 was cast on July 8, 1991. A mortar mixer was used to mix the polymer concrete (Figure 8). The polymer concrete was mixed for a minimum of five minutes prior to placing. This method of mixing resulted in the following problems:

a) Mixing blades jammed several times during and after adding the coarse aggregate.

b) Polymer concrete did not discharge readily from the mixer and had to be scraped out with a trowel into 5 gallon pails prior to placing in the form.

As a result of the above problems, the remaining batches of polymer concrete were mixed in a pail using a jiffler mixer (Figure 9). This method was labour intensive, but worked

much better than the mortar mixer; however, the capacity of the mixing pails resulted in only being able to mix one batch at a time and only 1/3 bag of coarse aggregate could be added to each batch.

The new footing for tower leg 3 was cast on July 9, 1991. The mortar mixer was replaced with a 4 cu ft concrete drum mixer (Figure 10).

This alternative method of mixing the polymer concrete provided the following advantages:

(a) The polymer concrete mixed very easily in the drum mixer and produced slightly better workability.

(b) The material discharged readily from the mixer into 20 L pails and only a small amount had to be scraped from the sides with a trowel (Figure 11).

(c) The drum mixer was easier to clean after use.

4.0 PLACEMENT OF POLYMER CONCRETE

Observations made during and after placing the polymer concrete are outlined in Table 3.

Tower Leg 2

At the completion of mixing, the polymer concrete was placed into the form using 20 L pails (Figure 12). Since insufficient material was available on site during placing of tower leg 2, wooden inserts had to be installed in the Sonotube (Figure 12). Large pieces of clean dry rock were then placed in the centre of the form and encapsulated with polymer concrete. Once the form was filled, the surface of the polymer concrete was finished with a trowel and allowed to cure for approximately two hours before the formwork was removed and the tower lowered (Figure 13).

Tower Leg 3

The same procedures as described above for tower leg 2 were followed for tower leg 3. A view of the footing after removal of the formwork is shown in Figure 14. Crease lines

created by the plastic used in the formwork are evident in the polymer concrete; however, they are not expected to affect the performance of the footing.

5.0 OBSERVATIONS

The I-beam and mechanical jacks provided a safe and efficient method for raising the tower legs and replacing the concrete footings.

The wooden formwork proved to be more practical than the Sonotube. Also, a smaller volume of polymer concrete was required to fill the form. Furthermore, the wood was sealed with plastic for easy removal and thus could be reused.

The VLT polymer concrete was generally stiff at the higher aggregate/resin ratio of 13.0/1.0, but workable at the 8.5/1.0 ratio. The concrete drum mixer proved to be the most effective for mixing the polymer concrete and improved the workability. A reduction in labour time and fewer complications were encountered when using the wooden formwork and the drum mixer.

6.0 RECOMMENDATIONS

Where the VLT polymer concrete is used for future tower footing replacement, the following procedures are recommended:

1. Use wooden formwork wrapped in plastic.

2. Mix polymer concrete in a drum mixer.

3. (a) The first batch of polymer concrete should be mixed and placed at an aggregate to resin ratio of 8.5/1.0 to ensure adequate wetting of the rock surface.

   (b) Subsequent batches of polymer concrete should be used at an aggregate to resin ratio of 13.0/1.0.

(c) The final batch of polymer concrete should be mixed at an aggregate to resin ratio of 8.5/1.0 for ease in finishing the top surface.

The compressive strength of the concrete removed is relatively low and it is recommended that a thorough investigation of the condition of the remaining footings be undertaken. Any decision to replace them should be made only after evaluation of the results of such investigation.

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TABLE 1

OBSERVATIONS OF THE CONDITION OF CONCRETE FOOTINGS PRIOR TO AND DURING REMOVAL
TOWER 2E6 - LEG 2 AND 3

TOWER LEG	EXISTING FOOTING CONCRETE DIMENSIONS (IN)			OBSERVATIONS OF CONDITION OF EXISTING CONCRETE FOOTING	METHOD OF REMOVING EXISTING CONCRETE FOOTING	OBSERVATIONS MADE DURING REMOVAL OF CONCRETE FOOTING	REQUIRED TIME TO REMOVE CONCRETE FOOTING (MIN)
	LENGTH	WIDTH	DEPTH				
2	42	31	6 to 11	Concrete surface around periphery of steel baseplate severely cracked and deteriorated. Damage appears to be mainly a result of freeze/thaw cycles. When sounded with a mason's hammer, numerous hollow spots detected indicative of delaminated concrete. Concrete when sounded crumbled into small pieces. Depth of deterioration varied from full depth along the sides (ie; 6" to 11") to 1" to 4" along top surface. Centre section of concrete appears to be intact between steel supports of baseplate.	Jack-hammer/ Sledge-hammer, Shovels	During jackhammering concrete broke away in small pieces (ie; aggregate size pieces). Adhesion of aggregate to cement paste was poor. Periphery of concrete around outside of baseplate was very easy to remove. Concrete underneath baseplate awkward to remove due to access; however, concrete crumbled into very small pieces indicative of a poor quality material. No large pieces of concrete were recovered intact.	29
3	42	31	8 to 12	Concrete surface around periphery of steel baseplate severely cracked and deteriorated. When sounded with a mason's hammer, numerous hollow spots detected indicative of delaminated concrete. Depth of deterioration varied from approximately 1" to 4" along top surface. Sides of footing contained a considerable amount of honeycombed concrete. However, when sounded with a mason's hammer, material appeared to be intact.	Jack-hammer/ Sledge-hammer, Shovel	During jackhammering, concrete crumbled into aggregate size pieces. Periphery of concrete around outside edge of baseplate easy to remove. Concrete underneath baseplate was more awkward to remove. It appeared that the quality of concrete underneath the baseplate was better; however, the quality (ie; low compressive strength) was still questionable. Generally the concrete crumbled into small pieces when jackhammering; however, a few small to medium chunks of concrete were removed intact. (See note)	40

(CV22A)

Note: Several chunks of the concrete were brought to the laboratory and test specimens 75x150 mm were cored and tested for compressive strength. The strength varied from 13 to 16 MPa.

TABLE 2

ROCK SURFACE PREPARATION, INSTALLATION OF FORMWORK AND MIXING OF POLYMER CONCRETE

TOWER LEG	TYPE OF ROCK SURFACE PREPARATION	TYPE OF FORMWORK AND DIMENSIONS	TIME REQUIRED TO PREPARE AND INSTALL FORMWORK (MINS)	METHOD OF SEALING FORMWORK	TYPE OF EQUIPMENT AND TIME REQUIRED TO MIX POLYMER CONCRETE				REMARKS
					MIX BASE RESIN AND CATALYST	MIXING TIME (MIN)	MIX AGGREGATE AND RESIN	MIXING TIME (MIN)	
2	Compressed air used to clean rock surface and remove loose material	42" dia Sonotube cut to fit profile of rock. Sonotube split to fit around footing, then held together by nailing wood to the outside at the seam in the Sonotube.	34	Formwork scribed to fit rock contour; then dirt placed around outside of formwork.	Gas powered drill with a jiffler mixer	2	Mortar mixer	5	Very difficult to mix polymer concrete in mortar mixer, especially after adding coarse aggregate. Mixer blade jammed along side of container. Polymer concrete also very difficult to remove from mortar mixer and had to be scraped out using a trowel into 5 gallon pail prior to placing in form. Two batches of polymer concrete mixed with mortar mixer (ie; 1 batch contained two 4 litre containers of VLT resin and catalyst, 2 bags of finely graded aggregate and 1/3 bag of coarse aggregate). Mortar mixer very difficult to clean out afterwards.
							Gas powered drill with jiffler mixer	5	Polymer concrete generally mixed very well in 5 gallon pail; however, mixing labour intensive. Also capacity of pail only allowed for addition of 1/3 bag of coarse aggregate. Two batches of polymer concrete mixed using this method. Batch size same as above.
3	Compressed air used to clean rock surface and remove loose material.	Wooden formwork 25" x 38". Wood sealed with plastic for easy removal and re-use.	20	Levelled formwork using 8"x8" wooden blocks on low end of rock. Once levelled, formwork nailed to wooden blocks. Placed dirt around outside of formwork.	Gas powered drill with a jiffler mixer	2	Drum Mixer	5	Polymer concrete mixed very well with a drum mixer. First batch contained three 4 L containers of VLT resin plus catalyst and 3 bags of finely graded aggregate. Remaining two batches contained three 4 L container of VLT resin and catalyst, 3 bags of graded aggregate and 1 bag of coarse aggregate. Majority of material in drum mixer discharged easily into 5 gallon pails. Small amount at end of each batch had to be scraped from mixer using a trowel. Drum mixer easy to clean afterwards by adding dry coarse aggregate, mixing for 5 minutes, then discharging aggregate.

(1) Since the formwork is reusable the time to install formwork would be greatly reduced (ie;≈ 10 mins)

(CV22A)

TABLE 3

OBSERVATIONS MADE DURING AND AFTER PLACING POLYMER CONCRETE

TOWER LEG	PROBLEMS ENCOUNTERED DURING PLACING OF POLYMER CONCRETE	QUANTITY OF POLYMER CONCRETE PLACED	CU. FT.	CONSISTENCY OF POLYMER CONCRETE	TIME (MIN)		
					TO JACK UP TOWER, REMOVE DETERIORATED FOOTING, PLACE POLYMER CONC. AND CLEAN UP	CURING TIME OF POLYMER CONC. AFTER PLACING AND FINISHING	FROM JACKING UP TOWER TO LOWERING TOWER
2	Transferring polymer concrete from mixer to pail. First batch of polymer concrete very dry due to wetting of inside of mortar mixer with resin. Insufficient polymer concrete brought to site; therefore wooden inserts installed in Sonotube and small to medium size clean, dry rock installed in formwork to ensure sufficient polymer concrete available to fill form.	Batch 1&2 - two 4 L container VLT resin and catalyst, 2 bags graded aggregate, 1/3 bag coarse aggregate Batch 3&4 - one 4 L container VLT resin and catalyst, 1 bag graded aggregate, 1/4 bag coarse aggregate.	2.5 1.25	Very stiff but workable mix. Stiff but workable mix	150	120	270
3	Generally polymer concrete mixed very easily in a drum mixer producing a very uniform quality with slightly better workability. Only small amount of each batch towards end of emptying drum mixer had to be scraped from sides of container with a trowel. Small to medium size clean, dry rock installed in formwork to reduce volume of polymer concrete.	Batch 1 - three 4 L containers VLT resin and catalyst, 3 bags graded aggregate Batch 2&3 - three 4 L containers VLT resin and catalyst, 3 bags graded aggregate, 1-1/2 bags coarse aggregate.	1.5 4.5	Very workable mix Stiff to workable mix	75	120	195

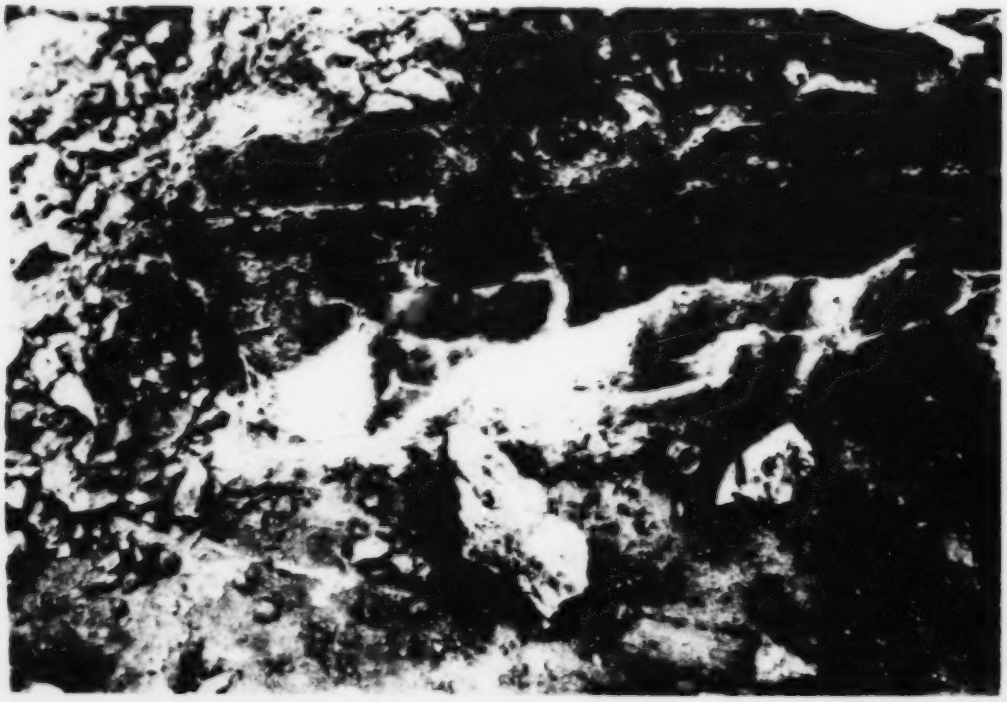
(CV22A)

Figure 1
View Of 115 kV Tower Line (Right Side)

Tower line built around 1946 and runs from Birch TS to Moose Lake TS

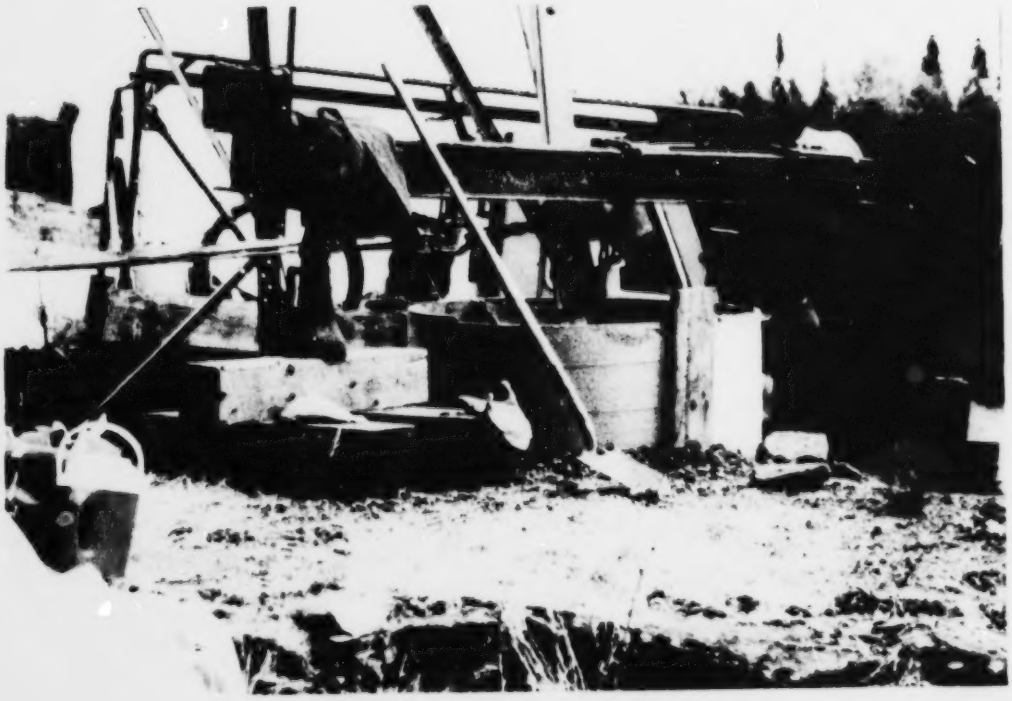
Figure 2
Condition Of Existing Concrete Footings

Overview of existing concrete footing.



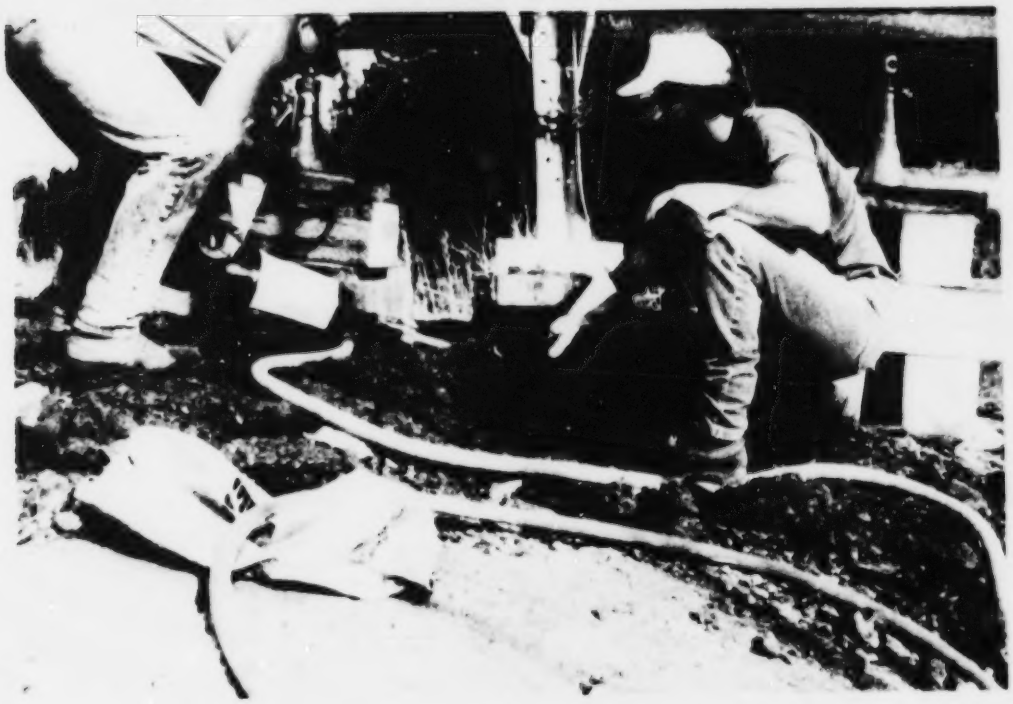
Significant deterioration of concrete. Concrete delaminated and extensively cracked. Damage appears to be due to freeze/thaw cycles.

Figure 3
Procedure Used For Raising Tower Leg

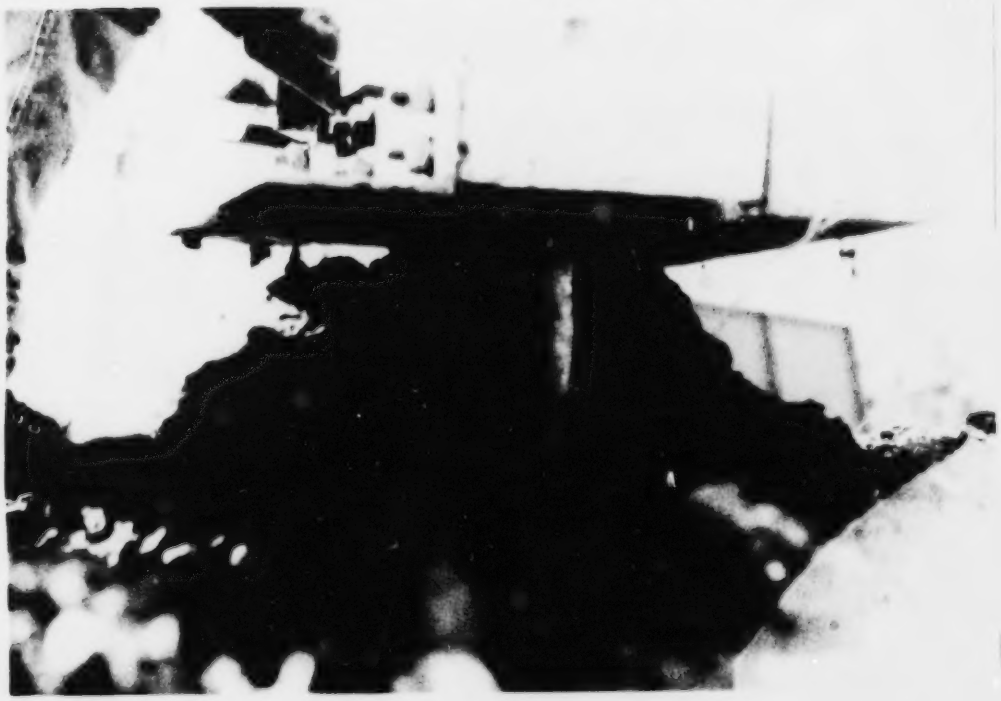


An I-beam was fastened to the tower leg with chains which were tensioned to hold the I-beam in place. The tower was then raised by the mechanical jacks to take the load off the existing footing.

Figure 4
Equipment Used To Remove Existing Concrete Footing

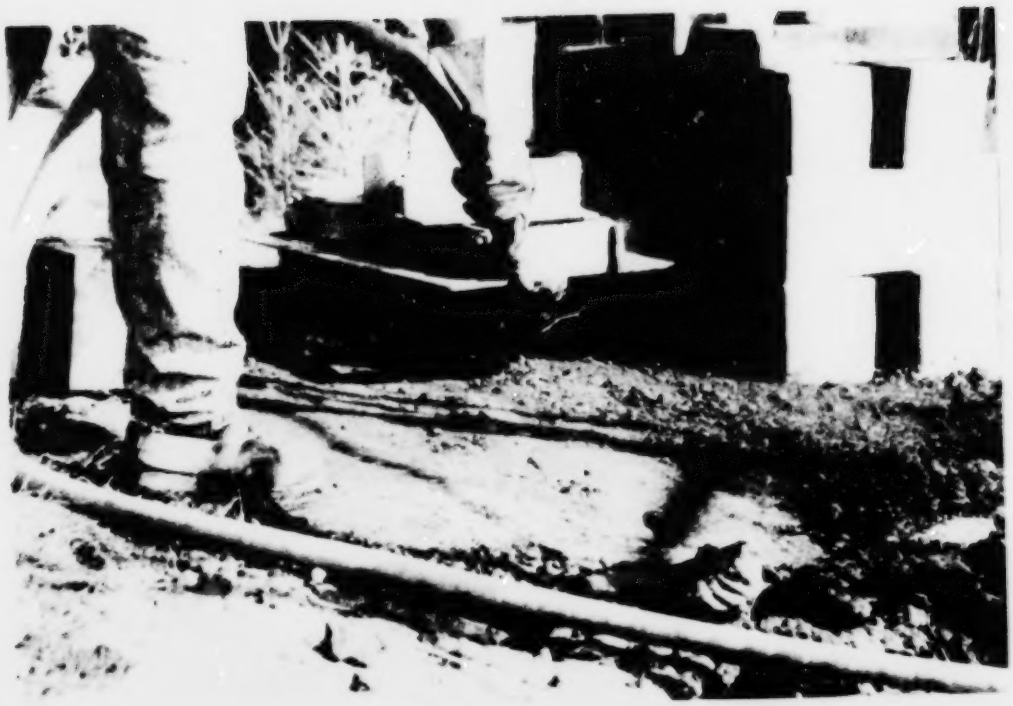


An air driven jackhammer was used to remove footing.



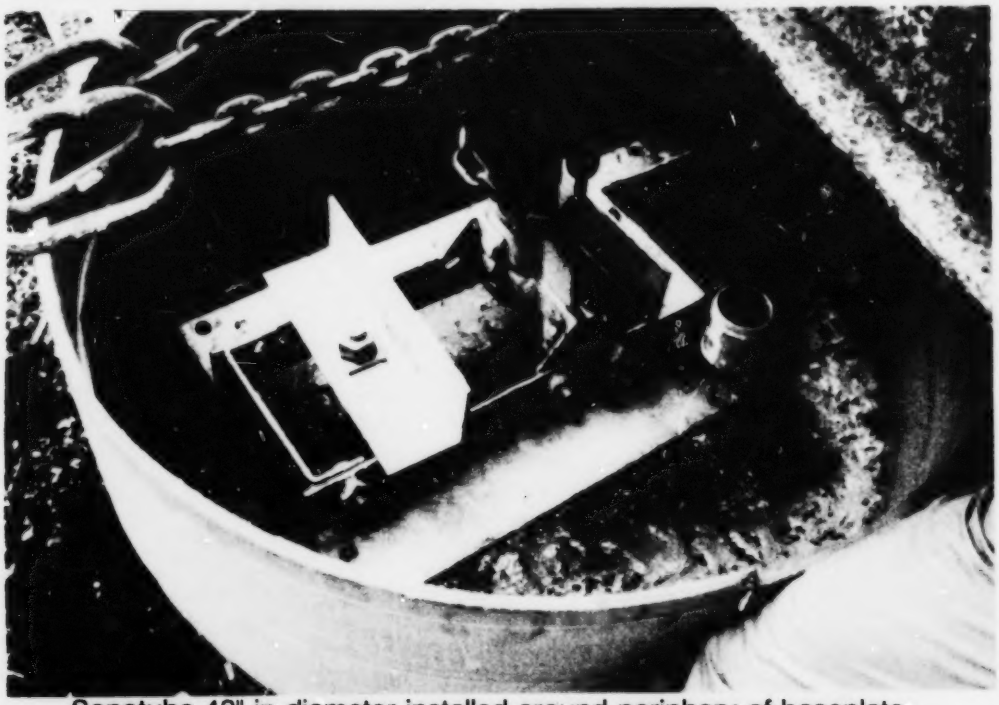
Concrete breaks apart into very small pieces during jackhammering, indicative of deteriorated concrete.

Figure 5
Cleaning Of Rock Surface



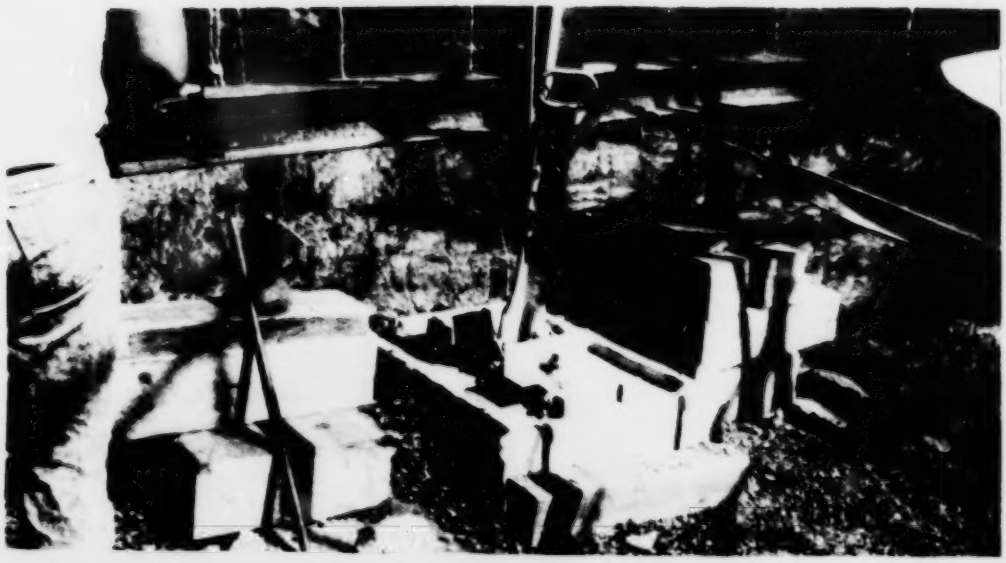
Because adhesion of the existing concrete to rock was poor and the rock was dry, the loose debris underneath the baseplate was removed using air pressure. No other surface preparation was necessary.

Figure 6A
Preparation Of Rock Surface And Construction Of Formwork / Tower Leg 2



Sonotube 42" in diameter installed around periphery of baseplate.
Surface of rock primed with VLT resin.

Figure 6B
Tower Leg 3

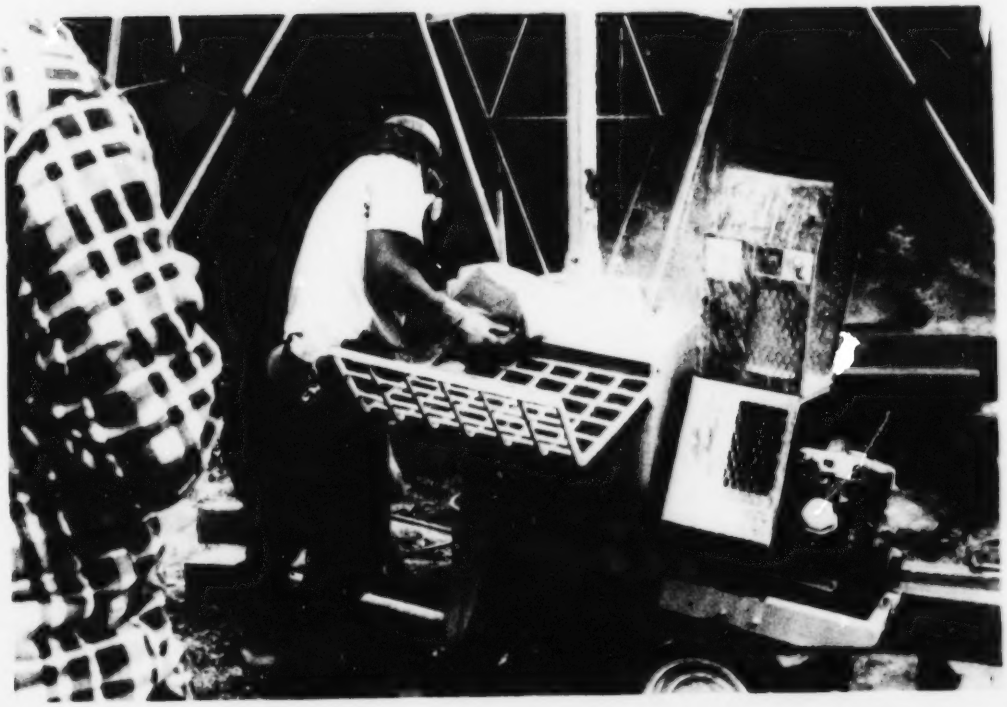


Wooden Formwork (38" by 25") lined with plastic installed around periphery of baseplate. Plastic used for easy removal of formwork and reuse.

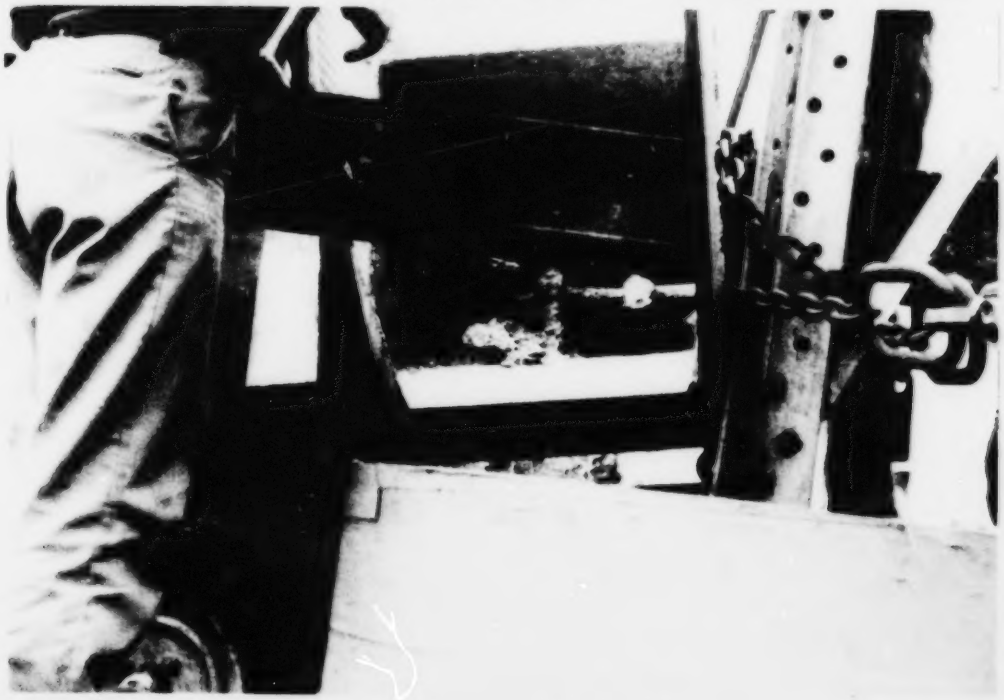
Figure 7
Mixing Two Components Of Resin

The powdered catalyst was added to the resin and mixed for a minimum of 2 minutes using a jiffler mixer attached to a gas powered drill.

Figure 8
Mixing of Polymer Concrete
Tower Leg 2



Mortar mixer initially used to mix polymer concrete. Mixing time 5 minutes.



Mortar mixer jammed several times during and after adding the coarse aggregate.

Figure 9
Mixing of polymer concrete.
Tower Leg 2

After abandoning the mortar mixer, the remaining batches of polymer concrete were mixed in a pail using a jiffler mixer. Mixing time: 5 minutes.

Figure 10
Mixing of Polymer Concrete.
Tower Leg 3

General overview of work area.

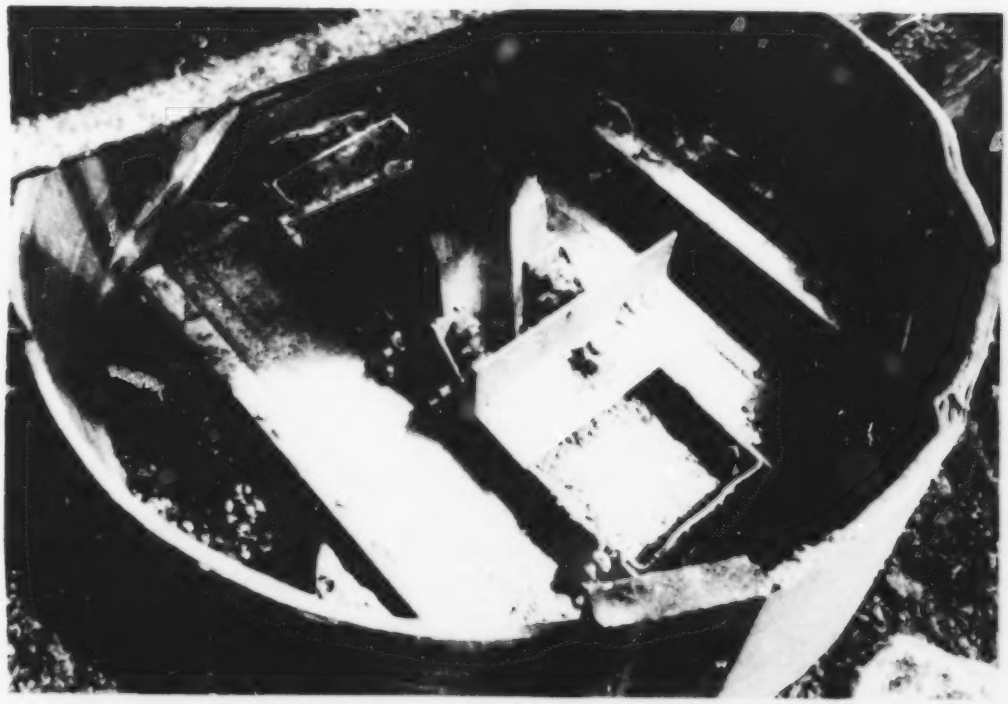
A 4 cu. ft. concrete drum mixer was used to mix polymer concrete. Mixing time: 5 minutes.

Figure 11
Mixing of Polymer Concrete
Tower Leg 3

Majority of material in drum mixer discharged easily into 5 gallon pails. Small amounts at the end of each batch had to be scraped from mixer using a trowel.

Figure 12
Placement of Polymer Concrete
Tower Leg 2

Polymer concrete placed in form using 5 gallon plastic pails.



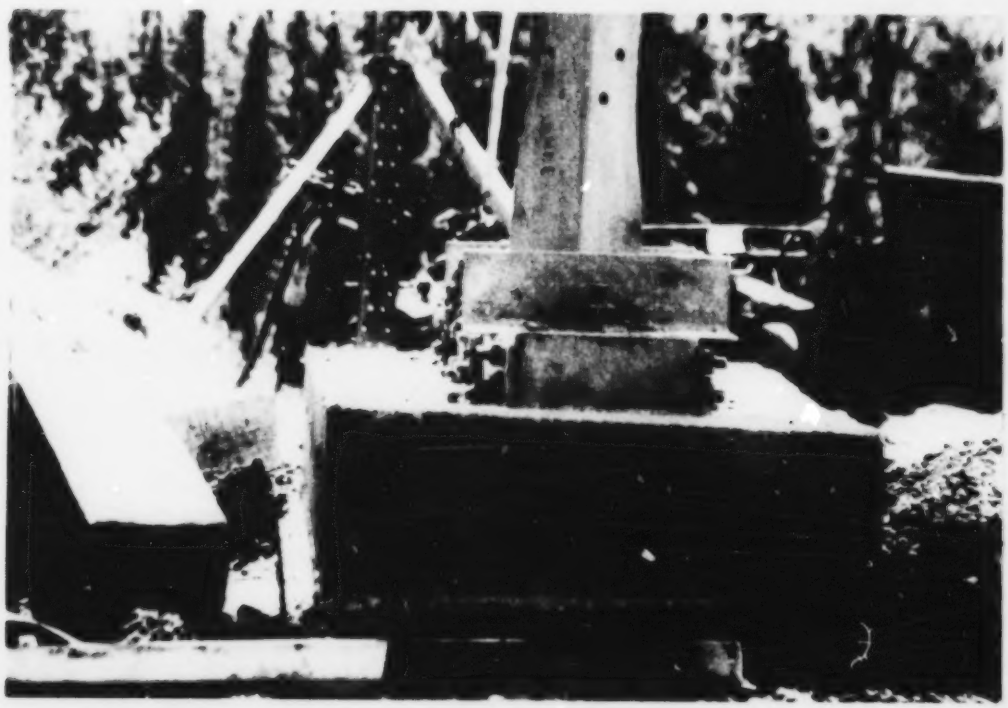
Insufficient material available on site to cast footing; therefore, new wooden forms placed inside the Sonotube to reduce volume of material.

Figure 13
View of Polymer Concrete Footing
Tower Leg 2

After 2 hours of curing, the formwork was stripped, the tower was lowered and the mechanical jacks removed.

Figure 14
View of Polymer Concrete Footing
Tower Leg 3

After 2 hours of curing polymer concrete, the formwork was removed.



Finished footing contains crease lines created by plastic placed in formwork.